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Infrared Propagation in Radar Frequency Ducting Conditions

B.J. Kachoyan and C.L. Morgan

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Infrared Propagation in Radar Frequency Ducting Conditions

B.J. Kachoyan and C.L. Morgan

Maritime Operations Division
Aeronautical and Maritime Research Laboratory

DSTO-TN-0068

ABSTRACT

This report investigates radar frequency (RF) and infrared (IR) propagation under the same atmospheric conditions to study to what extent IR detection systems can plug the 'holes' in RF detection caused by the presence of evaporation and surface based ducts.

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Infrared Propagation in Radar Frequency Ducting Conditions

Executive Summary

The propagation paths of electromagnetic radiation are determined by the vertical spatial derivative of the refractive index of the propagation medium.

Under 'standard' conditions the refractive index decreases linearly with altitude, leading to curved ray paths. There are several so-called 'anomalous' propagation conditions, however, which differ from the standard conditions described above. These include superrefractivity, subrefractivity and ducting. Only the latter was discussed in any detail here as it occurs most frequently and is of most relevance to anti-air warfare (AAW) applications at low altitudes.

While the propagation of RF radiation in ducting conditions is reasonably well understood, there appears to be little quantitative work on the propagation of infrared (IR) radiation under similar conditions. Shipborne infra-red search and track (IRST) systems are now being used to detect sea-skimming missiles and are candidates for being included, for example, as part of the FFG Progressive Upgrade Project. They are being marketed as complementary sensors to RF sensors and are planned to be used to cue radar systems (both phased array and fire control radars). This study investigated the simultaneous RF and IR propagation to study to what extent IR detection systems can plug the 'holes' in RF detection caused by the presence of ducts.

Surface ducting refers to a refractivity condition which traps the propagating energy over extended ranges in the proximity of the earth's surface. Two different RF ducts are possible. The evaporation duct is always present over the sea surface and has an average height of about 18 m in the Northern regions of Australia (henceforward referred to as the North). The surface-based duct occurs at higher altitude and is caused by meteorological conditions. It is present up to 34% of the time in coastal regions to the NW of Australia.

The ducts as described above are applicable to RF frequencies. This report compares the refractivity at RF and IR frequencies and the structure of the ducts under the same meteorological conditions.

It was noted that similar equations can be derived for infrared (IR) and radar frequency (RF) refractivity, making comparison easier.

The ducting equations show that humidity gradients have a much greater impact on the production and extent of ducts at RF frequencies than at IR frequencies. The same is true, to a lesser extent, for temperature gradients.

Finally, it was confirmed that infrared propagation is not significantly affected by conditions which lead to RF evaporation and surface-based ducting.

On the other hand, further work is required to determine whether conditions which could cause IR ducting in an ocean environment can occur to the North.

Contents

List of Figures

1. Introduction

The propagation paths of electromagnetic radiation are determined by the refractive index of the propagation medium. In particular, using ray terminology for the time being, the propagation path shape is determined by the vertical spatial derivative of the refractive index. This is an application of Snell's law in optics to continuously varying refractive indices.

Under 'standard' conditions the refractive index decreases linearly with altitude, leading to curved ray paths. There are several so-called 'anomalous' propagation conditions which differ from the standard conditions described above. These include superrefractivity, subrefractivity and ducting. Only the latter is discussed in any detail here as it occurs most frequently and is of most relevance to anti-air warfare (AAW) applications at low altitudes.

While the propagation of radar frequency (RF) radiation in ducting conditions is reasonably well understood, there appears to be little quantitative work on the propagation of infrared (IR) radiation under similar conditions. Shipborne infrared search and track (IRST) systems are now being used to detect sea-skimming missiles and are candidates for being included as part of the FFG Progressive Upgrade Project. They are being marketed as complementary sensors to RF sensors and are planned to be used to cue radar systems (both phased array and fire control radars). This study investigates RF and IR propagation under the same atmospheric conditions, to study to what extent IR detection systems can plug the 'holes' in RF detection caused by the presence of ducts.

Surface ducting refers to a refractivity condition which traps the propagating energy over extended ranges in the proximity of the earths surface. The trapping is caused by a change in the vertical gradient of the (modified) refractive index, the duct height being defined as the height at which this gradient changes from a negative to a positive value.

Two different effects lead to two different types of surface duct. The first effect is always present over the sea and is caused by a rapid decrease in humidity between the sea surface (at 100% relative humidity) and the drier ambient air above [6]. This is known as the evaporation duct and generally has heights less than 30 m.

The second environmental effect is a stable temperature inversion trapping humid air. This phenomenon is much less predictable and has greater spatial variability. Lower altitude inversions produce surface-based ducts, which have typical duct heights of 50-200 metres. Much higher ducts are possible but they are not relevant here. The surface-based duct is most common in coastal regions and are very rare in open ocean conditions. In certain geographical locations (notably the Persian Gulf), they can be present more than half the time.

The ducts as described above are applicable to RF frequencies. This report compares the structure of the ducts caused by the same meteorological conditions at IR frequencies.

2. Calculation of Refractive Index from Bulk Quantities

In discussion of electromagnetic refractive index, it is convenient to talk in terms of the refractivity N, with N= (n-1) × 10^6, where n is the refractive index. Another commonly used variable is the modified refractive index M, given by

$$M(z) = N(z) + 10^6 \times z/a_e, \tag{1}$$

where z is the height at which the index is being calculated (noting that N is also a function of z as will be discussed below) and a_e is the radius of the earth. Whether M or N are used varies according to the application and both are often used in a single discussion. The variable M is often used in ducting calculations since it can be shown that a trapping duct occurs where there is a change of sign in dM/dz [1]. For an evaporation duct, the duct height is defined as the altitude when dM/dz = 0 (corresponding to dN/dz = -0.157 N units/m).

The refractive index of a gaseous (low density) medium can be approximated [2] using a classical oscillator model, as

$$n^2(\omega) = 1 + \sum_i \frac{\omega_i^2 \Delta\varepsilon_i}{\omega_i^2 - \omega^2}, \text{ or}$$

$$n \approx 1 + \tfrac{1}{2} \sum_i \frac{\omega_i^2 \Delta\varepsilon_i}{\omega_i^2 - \omega^2}, \tag{2}$$

where the summation is over all state transitions, ω is the propagation frequency, ω_i is the oscillation frequency of the transition and $\Delta\varepsilon_i$ is a constant for the transition directly related to the molecular charge, molecular mass, the number of molecules per unit volume and the free-space permittivity. The latter term can be related to the bulk quantities of temperature, dry air pressure and vapour pressure. In general then, the refractive index is a function of temperature, pressure and water vapour content (humidity). Transforming into an equation for N gives

$$N \approx \sum_i \frac{\omega_i^2 \Delta N_i}{\omega_i^2 - \omega^2} \tag{3}$$

where $\Delta N_i = \frac{1}{2} \times 10^6 \times \Delta\varepsilon_i$.

From [2], the refractive indices from the RF to the IR can be approximated by seven terms of the form given in equation (3). The constants involved are written in Table 1. This model is reported to be quite accurate at RF and accurate to ±0.5 N units for humid atmospheres in IR bands. The term in T^2 in Table 1 is caused by the line mixing effects at the low band-centre frequency of this term. It is this seventh term of the table which provides the greatest difference between the N value at IR and RF frequencies.

Table 1. Parameters for Oscillator model of atmospheric refractivity [2].
P_{dry}, P_{H2O} and T are the dry-air pressure (kPa), the water-vapour partial pressure (kPa) and the temperature (K) respectively. 1 kPa = 10 mbar.

Term Number	ω_i (GHz)	ΔN_i
1	∞	$237.2 \times P_{dry}/T$
2	3.417×10^6	$526.3 \times P_{dry}/T$
3	1.9×10^6	$11.62 \times P_{dry}/T$
4	3.344×10^6	$651.5 \times P_{H2O}/T$
5	1.121×10^5	$7.4 \times P_{H2O}/T$
6	4.78×10^4	$57.9 \times P_{H2O}/T$
7	3.746×10^3	$3.744 \times 10^6 \times P_{H2O}/T^2$

At RF frequencies, the refractivity from Table 1 can be approximated by the formula [2],

$$N_{RF} = \frac{776 P_{dry}}{T} + \frac{717 P_{H2O}}{T} + \frac{3.744 \times 10^6 P_{H2O}}{T^2} \tag{4}$$

and can be assumed to be independent of frequency. Neglecting the second term leads to the Debeye formula given by references [1, 3].

The vapour pressure of water can be related to the absolute or relative humidity, and the temperature by [2]

$$P_{H2O} = \frac{A\,T}{2170}, \text{ or } P_{H2O} = rh\, E_s(T), \tag{5}$$

where A is the absolute humidity in g/m³, rh is the relative humidity expressed as a fraction and $E_s(T)$ is the saturation vapour pressure (kPa), in turn given by [2]

$$E_s(T) = 2.4096\left({}^{300}\!/_{T}\right)^5 10^{(10-2950.2/T)} . \tag{6}$$

The vapour pressure of water can also be derived from the dew-point temperature, Td (here expressed in °C), by [4]

$$P_{H2O} = 0.1 * \exp(1.8099 + \frac{17.27 * Td}{Td + 237.3}) \tag{7}$$

As an example of the different magnitudes involved, under the standard conditions, P=101.3 kPa, T= 288.15 K and rh = 50% then N_{RF} = 313.3, while N_{IR} = 274.6 at 3μm.

3. Profiles of Refractivity Index

Clearly, the bulk quantities in the calculation of the refractivity are dependant on height above the sea surface. The dry-air pressure profile is relatively insensitive to environmental conditions and can be approximated by the hydrostatic approximation at lower altitudes, vis [5]

$$P(z) = P_0 \exp\left(-(g / RT)\, z\right), \tag{8}$$

where g is the acceleration due to gravity (9.8 m/s) and R is the gas constant for dry air (287 J/kg/K). The values of P_0 and g/RT do not vary much within the typical parameters and they are generally considered constant. Furthermore, since g/RT is generally small ($\approx 1.2 \times 10^{-4}$), one often retains only the first two terms in a Taylor expansion of (8), so that

$$P \approx P_0 - P_0\,(g/RT)\, z. \tag{9}$$

'Standard' temperature and humidity profiles on the other hand can vary considerably with local conditions.

As mentioned above, propagation is dependant on the vertical derivative of the refractivity. Equation (3) and Table 1 show that N can be written as

$$N = \frac{\alpha_1 P}{T} + \frac{\alpha_2 e}{T} + \frac{\alpha_3 e}{T^2}, \tag{10}$$

where P = P_{dry} and e = P_{H2O}, the change of notation being for ease of use and compatibility with references [3 and 5].

The derivative dN/dz can then be written as

$$\frac{dN}{dz} = \beta_1 \frac{P}{dz} + \beta_2 \frac{dT}{dz} + \beta_3 \frac{de}{dz}, \tag{11}$$

where

$$\beta_1 = \alpha_1 / T, \beta_2 = \tfrac{-1}{T^2}\left(\alpha_1 P + \alpha_2 e + 2\alpha_3 e / T\right), \text{and } \beta_3 = \tfrac{1}{T}\left(\alpha_2 + \alpha_3 / T\right).$$

Since, from (9), dP/dz is a constant, the gradient of the refractivity is thus dependant on the temperature and humidity gradients. In particular, evaluating (11) at sea level for the 'standard' atmosphere (P_0=101.3 kPa, T=288.15 K, e=1.013 kPa) at RF reduces to

$$\frac{dN}{dz} = -0.032 - 1.263\frac{dT}{dz} + 4.495\frac{de}{dz}, \tag{12a}$$

while at the 3µm IR wavelength, it reduces to

$$\frac{dN}{dz} = -0.032 - 0.954\frac{dT}{dz} + 0.226\frac{de}{dz}. \tag{12b}$$

The 'standard' atmosphere is also such that the refractive index changes linearly with height (for moderate altitudes). As a result, the rays propagate with constant curvature of a radius a multiple of the earth's radius. This radius index K is derived from

$$K = \left(1 + 10^{-6} a_e \frac{dN}{dz}\right)^{-1} \approx \left(1 + 6.37\frac{dN}{dz}\right)^{-1},$$

where the derivative is taken at z=0.

This constant is approximately 4/3 in standard conditions at sea level, as defined above, where dN/dz = -39. In tropical conditions, notably at higher humidities, this constant is closer to 1.5 or greater, leading to an expected increase in nominal detection ranges of about 5% over temperate regions. At IR wavelengths this constant is closer to 1.27 for standard conditions (where dT/dz and de/dz are determined from the adiabatic lapse rate formulae for homogeneous air given in reference [1].)

4. Evaporation Ducts

Since the constants in front of the temperature and humidity gradients in equation (12) have opposite signs, the gradients need not be of opposite signs to alter the sign of dN/dz. In particular, near the sea surface, there is always a large humidity gradient since the sea itself is at 100% relative humidity. This causes the evaporation duct at RF frequencies.

From Section 2 the duct height occurs when dN/dz = -0.157. Equation (12) then shows that duct heights are given by the value of z which satisfies

$$\text{at RF: } -1.263\frac{dT}{dz} + 4.495\frac{de}{dz} = -0.125 \tag{13a}$$

$$\text{and at IR: } -0.954\frac{dT}{dz} + 0.226\frac{de}{dz} = -0.125 \tag{13b}$$

Comparing these two equations it can be seen that the RF ducting conditions are much more driven by the presence of humidity gradients than IR, with a smaller similar effect of temperature.

The temperature and humidity gradients close to the sea surface are quite complex because of the convection caused by those gradients and turbulent mixing at low altitudes. The calculation of the duct height in general conditions was given in reference [3] and can be calculated from the bulk quantities measured at an arbitrary reference height. A brief description is given in Appendix 1.

Figures 1 and 2 show the variation in evaporation duct heights with air-sea temperature difference, relative humidity and wind speed, for a measurement height of 10 metres. Relative humidities of 90% and 30% were chosen as two extremes for illustration. The figures are not plotted beyond the region of validity of the theory ($z/L \gtrsim 0.1$).

Since typical air-sea temperature differences in the Northern regions of Australia (henceforward referred to as the North) are less than one degree, the IR duct height is much lower than the RF duct height and in most practical cases can be considered negligible.

Sample evaporation ducts in tropical conditions as a function of height are shown in Figure 3, showing the weakness of the IR duct and conversely the strength of the RF duct.

Ducting conditions specific to IR propagation are common on land and these are usually caused by temperature inversions. The prevalence of the equivalent phenomenon in open ocean conditions, especially to the North, is expected to be rare but further work is required on climatological data to confirm this. From Figures 1 and 2 it appears that low relative humidity conditions, together with the air temperature being significantly greater than the sea temperature, lead to increased IR evaporation duct heights.

5. Surface-based ducts

As mentioned in the introduction, surface ducts are caused by macro meteorological conditions and are not amenable to generalised analysis as are evaporation ducts. For a simple discussion, we consider two temperature and humidity profiles which give typical surface-based ducts. The profiles used were supplied by Microwave Radar Division from their comprehensive database of Northern climatological conditions. The profiles are from the Broome region and the Ducting Climatology Summary database from the Naval Command Control and Ocean Surveillance Centre at San Diego calculates that a surface-based duct may be present up to 34% of the time in this area.

The profiles and the resultant modified refractivity profiles are shown in Figures 4 and 5. The second profile (Figure 5) also contains an evaporation duct in RF. It is clear from these diagrams that these conditions will only marginally affect the IR profile.

6. Conclusions

Similar equations can be derived for infrared (IR) and radar frequency (RF) refractivity. The term in T^2 in equation (10), namely the seventh term in Table 1, causes the greatest difference between the value of N at IR and RF frequencies.

Humidity gradients have a much greater impact on the production and extent of ducts at RF frequencies than at IR frequencies. The same is true, to a lesser extent, for temperature gradients.

Infrared propagation is not significantly affected by conditions which lead to RF evaporation and surface-based ducting.

Further work is required to determine whether conditions which could cause IR ducting in an ocean environment can occur to the North.

7. References

1. D.E. Kerr ed.
Propagation of short radio waves. IEE Electromagnetic Waves Series 24. Peter Peregrinus Ltd. 1987.

2. F.G. Smith ed.
Atmospheric Propagation of Radiation. The Infrared and Electro-optical Systems Handbook Volume 2. SPIE Press. 1993.

3. M.R. Battaglia.
Modelling the radar evaporative duct. RANRL Technical Note 3/85. April 1985. UNCLASSIFIED.

4. J.D. Turton, D.A. Bennetts, S.F.G. Farmer
An Introduction to Radar Ducting. Meteorological Office, Bracknell.

5. R.A. Paulus.
Evaporation Duct Effects on Sea Clutter. IEEE Transactions on Antennas and Propagation. Vol. 38, No. 11, November 1990.

6. Applied METOC Centre
The Ducting of Electromagnetic Transmissions. RAN METOC Services. October 1995.

8. Acknowledgment

Thanks to Microwave Radar Division for providing the temperature and humidity profile data for surface-based ducting conditions.

Appendix

The evaporation duct height is obtained from numerically solving the equation

$$N_* \phi_T\left(z/L\right) = -0.125\,K\,z \tag{A1}$$

for z. Here K is the Von Karman constant (≈0.4). The so-called stability length L must be first also calculated numerically by solving

$$L = \frac{u_*^2 T_a}{1.35Kg\left(T_* + 0.608T_s q_*\right)}. \tag{A2}$$

The quantities u*, T* and q* are the scaling factors of wind speed, temperature and mixing ratio respectively (note that the mixing ratio is related to the water vapour partial pressure *e* by *e* = 1630 *q*). They can be given in terms of the value of the bulk quantities at the height equivalent to the roughness length for momentum, $z = z_0 = 1.5 \times 10^{-4}$ (termed u_0, T_0 and q_0) and those at a reference height z_1 (i.e. u_1, T_1, and q_1). They are also functions of the stability length and are given by

$$u_* = \frac{Ku_1}{\left[\ln\left(z_1/z_0\right) - \psi_u\left(z_1/L\right)\right]},$$

$$T_* = \frac{K(T_1 - T_0)}{\left[\ln\left(z_1/z_0\right) - \psi_T\left(z_1/L\right)\right]},$$

and

$$q_* = \frac{K\left(q_1 - q_0\right)}{\left[\ln\left(z_1/z_0\right) - \psi_e\left(z_1/L\right)\right]}$$

The universal profiles ψ_x, where x = u, T or e, are given by

$$\psi_x\left(z/L\right) = \int_{z_0/L}^{z/L} \frac{1-\phi_x(\gamma)}{\gamma}\,d\gamma$$

where

$$\phi_u = \begin{cases} \left[1 - 18(z/L)\right]^{-1/4} & z/L < 0 \\ 1 + 4.5(z/L) & z/L \geq 0 \end{cases}$$

and

$$\phi_T = \phi_q = \begin{cases} \left[1 - 9(z/L)\right]^{-1/2} & z/L < 0 \\ 1 + 6.35(z/L) & z/L \geq 0 \end{cases}$$

It is customary to assume that all measurements have been made at a reference height z1 of 10m.

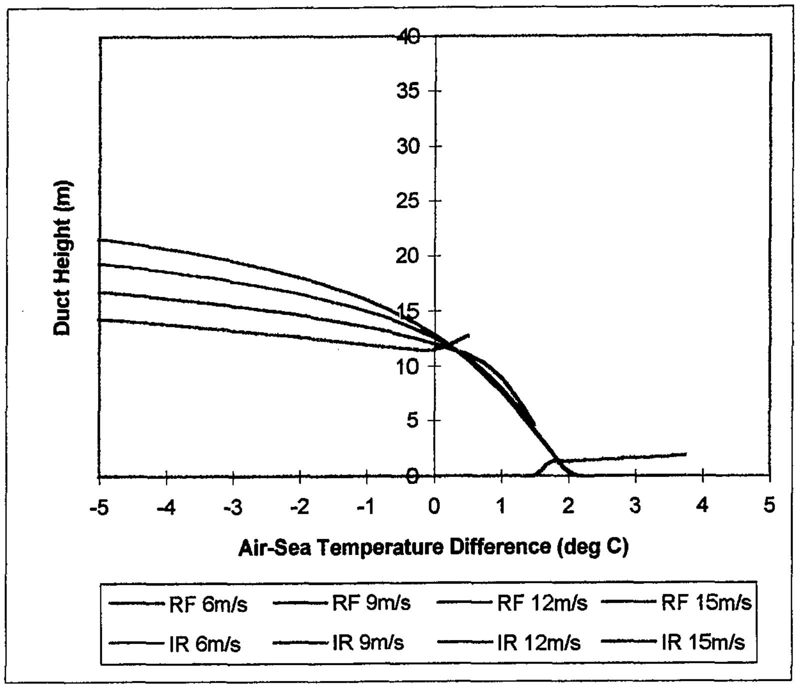


Figure 1. RF and IR Duct heights as a function of air-sea temperature difference, relative humidity and wind speed. (Sea temperature 28.5 °C, relative humidity 90%).

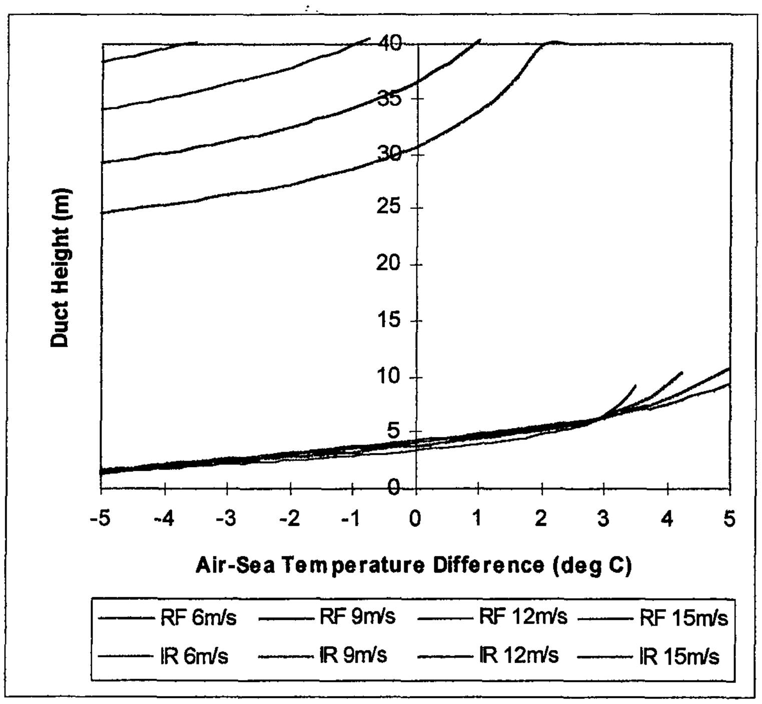
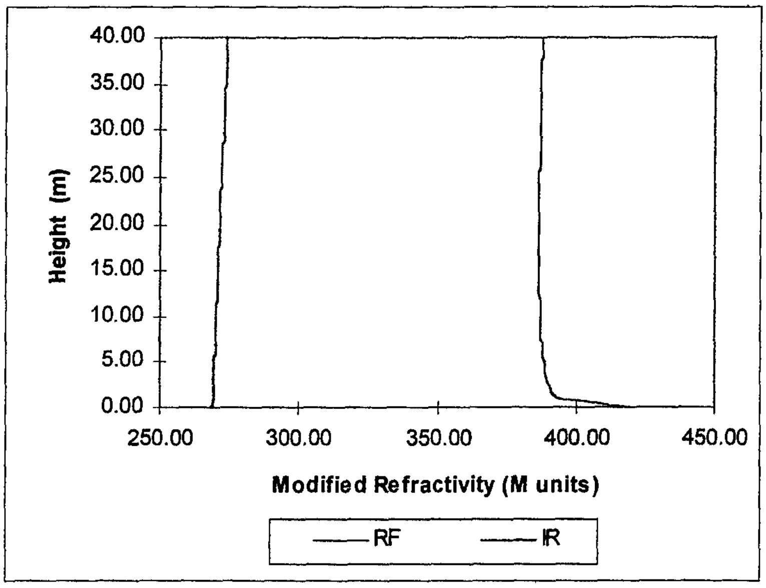


Figure 2. RF and IR Duct heights as a function of air-sea temperature difference, relative humidity and wind speed. (Sea temperature 28.5 °C, relative humidity 30%).



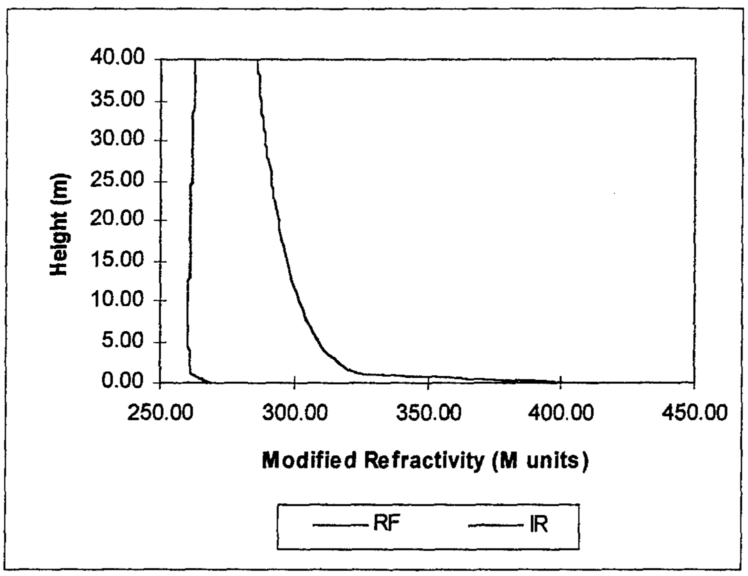


Figure 3. Sample RF and IR ducts in typical tropical conditions.

Top: Relative humidity 90%, sea temperature 28.5°C, air temperature 26.5°C, wind speed 15m/s. RF duct height 18.13m. IR duct height 0m.

Bottom: Relative humidity 30%, sea temperature 28.5°C, air temperature 32.5°C, wind speed 15m/s. RF duct height 40m. IR duct height 7.6m.

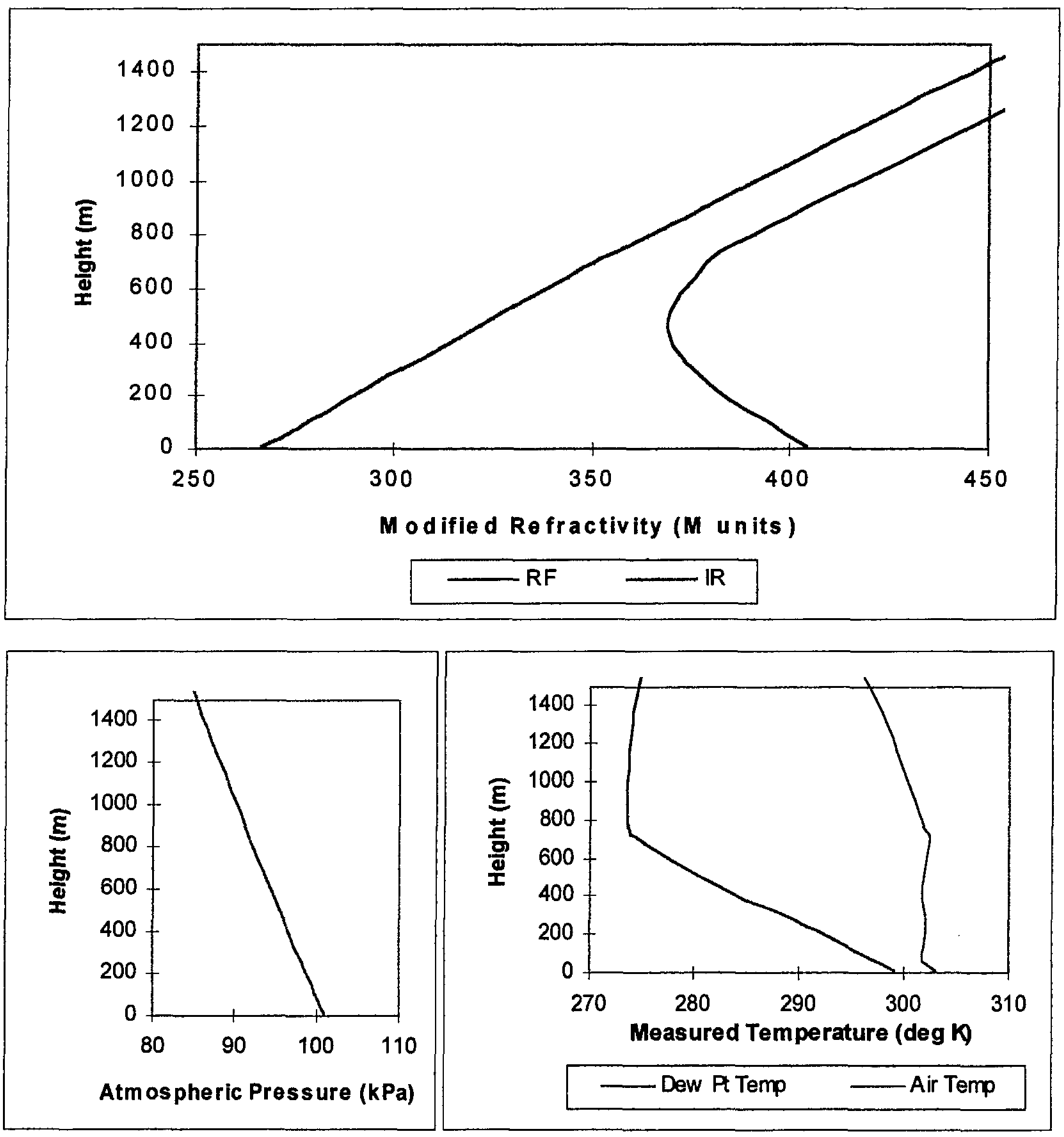


Figure 4. The modified refractivity profile and the associated pressure, air and dew point temperature profiles for a surface based duct in the Broome region.

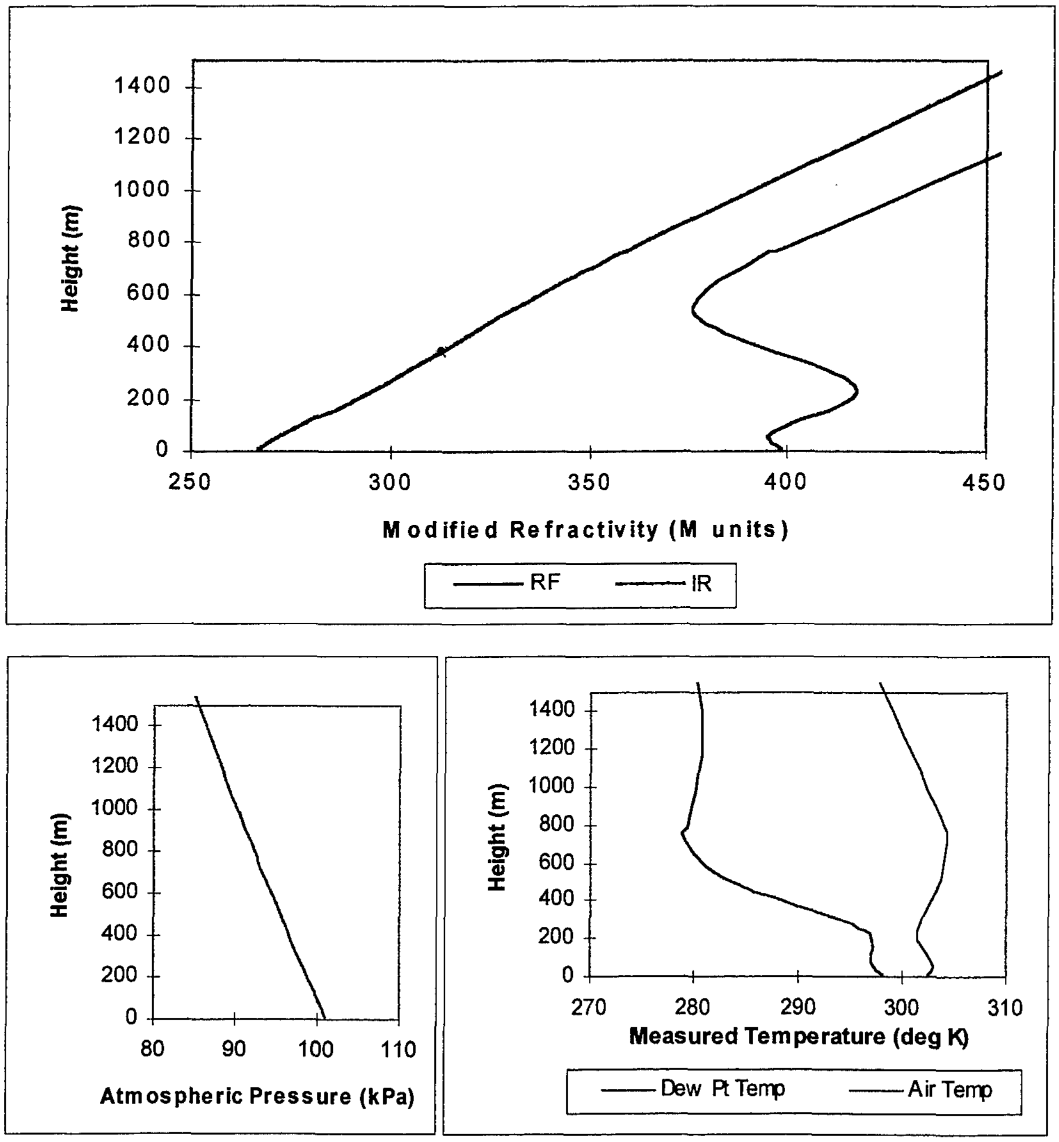


Figure 5. The modified refractivity profile and the associated pressure, air and dew point temperature profiles for a surface based duct in the Broome region. An evaporation duct is also present in the RF.

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B.J. Kachoyan and C.L. Morgan

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DSTO NUMBER	**DSTO-TN-0068**
AR NUMBER	**AR-010-109**
FILE NUMBER	**510/207/0706**
PREVIOUS Classification	**WAS:- LIMITED DOD**
REVISED Classification and Release Limitation	**UNCLASSIFIED** **Public Release**

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Mrs. Natalie Mahlknecht
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